CONTEMPORANEOUS DEFORMATION: A CRITERION FOR AQUEO-GLACIAL SEDIMENTATION

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Previous records of deformation in unconsolidated strata.—Deformation in unconsolidated strata has been observed and recorded by many writers on geological subjects. Faults having a displacement ranging from a fraction of an inch to a few feet are often seen in sections of glacial sandplains, eskers and kames, and in river terrace deposits.[1] Being due probably to removal of some lateral or subjacent supporting material, these faults are nearly always of the normal type. Folds in unconsolidated sediments are of much less common occurrence. J. B. Woodworth has figured and described such deformation in the kame gravels west of Fresh Pond, in Cambridge, Massachusetts.[2] These folds, having a height of as much as 10 feet, were overturned southward in a way to indicate that they had been formed by the thrust of a readvancing ice lobe. The same features were described a few years earlier by Woodworth and Marbut.[3] Similarly, contortion in the Columbia formation on Martha's Vineyard and Block Island has been ascribed to the pressure exerted by overriding Pleistocene ice.[4]

In all the instances noted above the deformation was in no way associated with the deposition of the beds. It was distinctly subsequent in point of origin. In the pages that follow is described a

[1] The present writer described one good example of this phenomenon several years ago (*Science* [IV], XXVIII [1908], 654).

[2] *Essex Institute Bull.*, XXIX (1898), 71.

[3] *U.S. Geol. Survey, Ann. Rept. 17* (1896), Pt. 1, p. 990.

[4] J. B. Woodworth, "Unconformities of Martha's Vineyard and of Block Island," *Bull. Geol. Soc. Am.*, VIII (1897), 197–212; "Glacial Origin of Older Pleistocene in Gay Head Cliffs . . . . ," *ibid.*, XI (1900), pp. 455–60. Shaler, at an earlier date, believed these folds were of orogenic origin. See, e.g., his "Report on the Geology of Martha's Vineyard," *U.S. Geol. Survey, Ann. Rept. 7* (1888), p. 345; and his "Tertiary and Cretaceous Deposits of Eastern Massachusetts," *Bull. Geol. Soc. Am.*, I (1890), 446–47.

kind of distortion, which is believed to have been contemporaneous with the accumulation of the strata.[1]

The Squantum slates described.—On the eastern coast of Squantum Head, in Boston Harbor, Massachusetts, is a series of slates

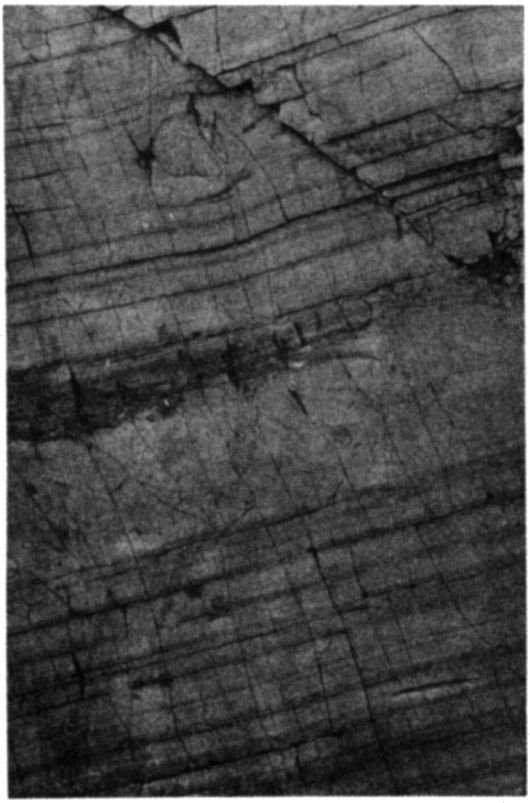

FIG. 1.—The Squantum banded slates. Near the middle of the picture is a zone in which the strata have been closely folded. Above this zone may be seen an isolated pebble, about three inches in diameter, which is thought to have been dropped by floating ice.

overlying the Squantum tillite.[2] The formation is of late Carboniferous or of Permian age. The slates are very fine-grained

[1] The same type of distortion was described by James Geikie in clay beds overlying till at Portobello, Scotland; see his *Great Ice Age* (3d ed., New York, 1895), pp. 271–74.

[2] R. W. Sayles, "The Squantum Tillite," *Bull. Mus. Comp. Zoöl.*, LVI, No. 2 (1914), 141–75.

sandstones and coarse and fine mudstones. These variations in texture are frequent, thus giving rise to a very uniform, closely spaced bedding lamination or banding (see Fig. 1). The strata have a pretty regular southeastward dip of 20°–25°. Minor undulations are seen here and there, but these are easily recognized as of orogenic origin and were no doubt formed at the same time with the larger deformation of which the inclination of the beds is evidence.

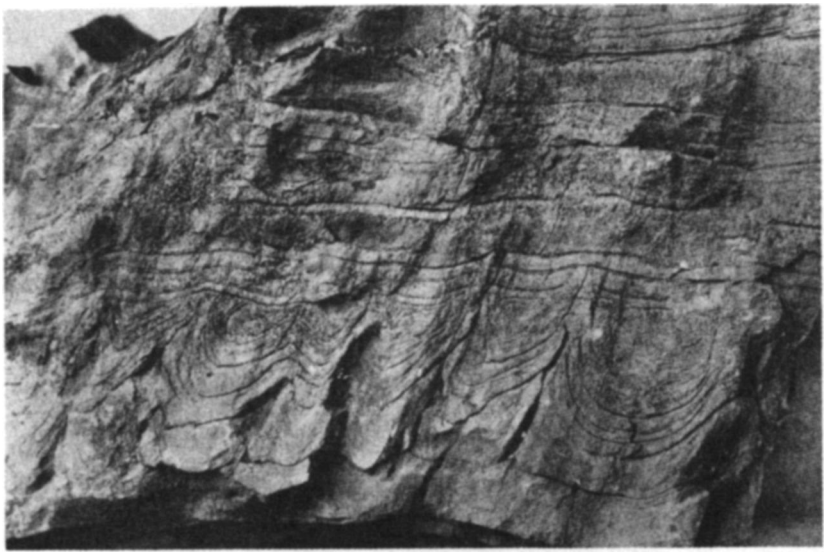

FIG. 2.—Hand specimen of the truncated folds seen at Squantum. Here the folds are not very strongly overturned. The length of the specimen illustrated in the figure is about eight inches.

At several stratigraphic levels in the series, at intervals of a few feet, are belts or zones in which the primary banding has been compressed into small folds (Fig. 1). Downward in the strata these folds diminish in size until they disappear, i.e., they grade into unfolded beds (Fig. 2). Above, they are sharply truncated by beds of similar nature, which have not been distorted. The little folds are all overturned in the same direction. Sometimes the overturning is slight, as in the figure. At other times the overturning may actually pass into overthrust faults having a displacement

of an inch or two. Zones showing this sort of distortion are not at all uncommon in the finer clastics of Squantum Peninsula.

Inferences as to the origin of the Squantum slates.—The characters of the Squantum slate series suggest the following conditions of origin: (1) Muds and silts were quietly accumulated in a body of water practically unaffected by currents, or, at least, by changing currents. (2) Occasionally a rigid body, submerged deep enough to touch bottom in places, floated by and here and there rubbed over

FIG. 3.—Contemporaneous deformation seen in unconsolidated sand at Woodland. The folds are truncated and overlain by horizontal strata as at Squantum. The photograph does not show the truncated portion of the folds because the beds are of very nearly the same texture at and near the surface of contemporaneous erosion. In the field, however, the relations are clear. The figure illustrates a section about twenty inches long.

the soft deposits, crumpling them and scraping off the crests of the folds. (3) After the disturbing agent had passed, quiet deposition continued as before.

In his visits with field classes to Squantum the writer was impressed by this peculiar phenomenon several years ago and he explained it as possibly due to floating blocks of ice. Corroborating this hypothesis is the presence of occasional isolated pebbles and

bowlders inclosed in the evenly banded slates (Fig. 1). These were thought to have been carried by the floating ice-blocks, and to have dropped as the ice melted. Mr. R. W. Sayles's study of the tillite of Squantum, cited above, is also confirmatory evidence.

The Auburndale deposits described.—Last November, at Auburndale, Massachusetts, the writer came upon a beautiful exposure of a structure exactly resembling the Squantum zones of deformation, but this time in unconsolidated deposits of a Pleistocene sand plain, (Fig. 3). The structure was seen in a sand pit. The deposit consists of fine and coarse sand and some clay, all regularly stratified with frequent variations in texture. As at Squantum, the zones are repeated at several stratigraphic levels and with no definite spacing or order. Here, then, is an example of aqueous deposition undeniably associated with glacial action. The likeness between the two cases is highly significant, particularly as regards the origin suggested.

Definition.—The relations described above are those of local unconformity associated with deformation of the upper layers of the subjacent strata. The structure is really *local angular unconformity.* Since erosion producing local unconformity is often called *contemporaneous erosion,* we may term the folding and faulting resulting from such erosion *contemporaneous deformation.*